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Living without cement

Prof Peter Claisse of Coventry University gives his views on the crucial need to establish the use of concrete alternatives which don't use cement, on sustainability grounds.

Establishing widespread use of a CEM0 – a sustainable material made without conventional cement – is crucial to securing the future of the construction industry. But the barriers will only be overcome when the industry becomes prepared to support large-scale research and pilot projects.

The production of one tonne of conventional cement produces almost its equivalent in CO2 – and 5% of all CO2 emissions globally. Alternatives are badly needed if the construction industry is to ride out the tide of legislation, landfill taxes and high carbon trading prices, and rising energy costs. Despite the urgency of the situation and the huge amount of research evidence from small projects, industry has been unwilling to make significant trials of zero carbon cement.

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There are currently three main solutions that are being researched to reduce the environmental impact of concrete: alternative fuels like shredded tyres or pelletised domestic waste to replace coal and oil in the kilns; waste minerals such as ashes or slags to replace the cement in the concrete, and different cements such as supersulphated cement and magnesia cements.

The problem with addressing fuel efficiency is that there is always going to be a significant proportion of emissions which are unavoidable – approximately 0.5 tonnes of CO2 are produced by the chemical reactions in the kiln. There have been considerable gains in the area of waste minerals with the introduction of the cement classes in EN197. Much of the bagged cement which is sold in the UK is CEMII with either ash, slag or limestone flour in it. Traditional practice for producing concrete in this country is, however, to add cement replacements at the batching plants, and there are a number of barriers to achieving more replacement: fly ash is classified as a waste under environmental legislation, making it difficult to transport and use; sources of coal are constantly changing (for example, the UK now imports much of its coal from areas as diverse as Indonesia and Siberia), and different coals produce very different ashes; and the mercury control on emissions from power stations makes unsuitable ash. There are also limited supplies of ash and slag. During a hot summer most of the coal-fired power stations are often shut down and ash is very difficult to store without adding water to make a slurry. A reduction in steel production means a reduction in supplies of slag.

Materials can only replace part of the cement – up to about 40% for PFA and about 60% for GGBS. A complete change in the basis of worldwide cement production is, however, unlikely in the foreseeable future. Supersulphated cements were withdrawn from the market about 50 years ago due to their poor shelf life. Coventry University has carried out a number of programmes based on replacing all the cement with waste materials and using waste gypsum and slag to make new types of supersulphated mixes. These mixes have been tested in an extensive series of site trials. The mixes without cement cannot achieve strengths above about 30MPa but there are numerous potential applications including sub-bases for roads. For example, trials were held on a section of a car park. The mix contained Basic Oxygen Slag, waste gypsum and kiln dust with no cement. This work has demonstrated that low strength concrete mixes which are suitable for a wide range of applications may be made using mineral wastes to replace all of the cement.

In order to be sustainable, a structure must be durable so that it lasts a long time with minimal resources required for maintenance. It is possible to make durable concrete. It is also very easy to make non-durable concrete - by adding too much water, for example. The problem is that there is no reliable test for durability. For the last 100 years concrete on most sites has only been tested for strength. The consequences of this are that vast numbers of structures are suffering durability problems, primarily corrosion of embedded steel. It has been known for 100 years that the main cause of this is chloride from salt. In the USA the cost of this has been estimated at 2% of GDP. To reach the steel the salt must move through the concrete. Most durability tests measure how easily salt (and other compounds) can move through it.

Our research group has developed a method to overcome the problems with the most popular durability test, the ASTM C1202 Rapid Chloride Penetration Test. The test works by measuring electromigration as the current through the sample under an applied voltage, and is widely used throughout the Americas and Asia. The problem is that it can be fooled by reducing the current with mixes with cement replacements which give high electrical resistivity but which are not particularly resistant to salt penetration. Our computer model is based on a fundamental understanding of the processes that take place during the test, taking into account the non-linearity of the results, and therefore giving a true measure of the potential durability of concrete mixes - a critical factor if industry is to be reassured of the quality of low carbon alternatives.

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